

Five-Decade National Trends and Forecasting of Brain Tumor Mortality Among Older Adults in the United States, 1968–2023

Ali Zubair

Sheikh Zayed Medical College and Hospital Rahim Yar khan

Anchit Chauhan

Maulana Azad Medical College

Amatul Hadi Hamdana

Dow University of Health Sciences

Falak Naz

Richmond University Medical Center

Minal Sajjad

Kabir medical college

Kanchan Chaudhary

Liaquat University of Medical & Health Sciences

muhammad sohaib anwer

Sheikh Zayed Medical College and Hospital Rahim Yar khan

Maaz Ahmed

Sheikh Zayed Medical College and Hospital Rahim Yar khan

Wishad Waris

Sheikh Zayed Medical College and Hospital Rahim Yar khan

Hakim Ullah Wazir

hakimwazir21@gmail.com

Lady Reading hospital Peshawar

Rida Shakeel

Dow University of Health Sciences

Research Article

Keywords:

Posted Date: May 18th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9285512/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Introduction / Objective:

Brain tumors remain a significant cause of neurological mortality in older adults. Despite advances in neuro-oncology, long-term population-level trends have not been comprehensively characterized. This study aimed to evaluate five-decade national mortality trends associated with brain tumors and forecast future patterns among U.S. adults aged ≥ 65 years using CDC mortality data.

Methods:

This retrospective population-based study utilized the CDC Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) database (1968–2023). ICD-8 (191), ICD-9 (191), and ICD-10 (C71) codes identified deaths with brain tumors as the underlying cause. Age-adjusted mortality rates (AAMRs) were standardized to the 2000 U.S. population. Temporal trends were assessed using Joinpoint regression to estimate average annual percent changes (AAPCs) with 95% confidence intervals (CIs). Future projections (2024–2035) were modeled using the autoregressive integrated moving average (ARIMA) method. Analyses were stratified by sex, race, age group, and U.S. Census region.

Results:

From 1968–2023, 311,680 deaths were recorded among adults aged ≥ 65 years. The mean AAMR was 15.2 per 100,000, peaking at 18.3 in 2021 (AAPC: 1.90; 95% CI: 1.6–2.2). ARIMA modeling projected an increase to 18.06 by 2035 ($p < 0.00001$) with satisfactory model adequacy (ADF $p = 0.63$; Box-Ljung $p = 0.30$). Mortality increased slightly faster in females than males (AAPC: 1.94 vs 1.82). The 65–74 age group had the highest burden (167,418 deaths). Non-Hispanic Black individuals showed the steepest rise (AAPC: 2.70), followed by White individuals (AAPC: 1.96). Regionally, the South experienced the fastest increase (AAPC: 2.19), while Vermont had the highest state-level burden (AAMR: 23.5 per 100,000).

Conclusion:

Over the past five decades, brain tumor-related mortality among older U.S. adults has risen steadily and is projected to continue increasing through 2035. The disproportionate rise among females, Black populations, and residents of Southern states highlights ongoing disparities in neuro-oncologic care, underscoring the need for equitable access to preventive and therapeutic interventions.

1. Introduction

Primary tumors of the central nervous system (CNS) are those tumors that arise from the tissues of the brain and CNS and are a diverse group of neoplasms that consist of both malignant and benign tumors [1, 2]. Every year, more than 300,000 cases of brain tumors are diagnosed globally, which makes it the 5th most prevalent type of cancer worldwide [3]. According to previous studies, brain and CNS tumors

are among the top ten causes of death and a main contributor to morbidity worldwide. They cause a high burden on healthcare systems due to their high mortality rate, causing disabilities, and reducing the overall quality of life [4]. The overall incidence of primary CNS tumors is the highest among the age group of 75–84 years [5]. According to the Global Cancer Observatory (GBLOBOCAN) 2020 estimates, the brain and CNS neoplasms are a very noticeable proportion of the global disease burden and rank 19th among the most frequent cancers, that is, 1.9% of all cancers, and are the 12th leading cause of cancer-causing deaths, that is, 2.5% of all cancers [6]. According to a US nationwide analysis in 2023, almost 24,810 cases and 18,990 deaths occurred due to CNS tumors [7].

Glioblastoma (49%), other gliomas with infiltration in the central nervous system (CNS) parenchyma (about 30%), primary CNS lymphoma (7%), and malignant forms of ependymomas (3%) and meningiomas (2%) are the different malignant brain tumors that present with the symptoms of headache (50%), seizures (20–50%), neurocognitive impairment (30–40%), and focal neurologic deficits (10–40%). According to this study, almost 85,000 people are diagnosed with primary brain tumors in the US every year, and 29% of cases are malignant brain tumors [8]. Even though in the USA, malignant brain tumors account for a small proportion of cancers, the 5-year survival rate is very low, ranging from 23 to 36% [9]. As the elderly population tends to grow faster compared to other age groups, the cases of primary brain tumors increase in the older population, and certain types of brain tumors are common among this population, including glioblastoma, anaplastic astrocytoma, and meningiomas, which tend to increase with age [5]. The most common malignant brain tumor is glioblastoma, and its occurrence increases after 40 years of age and reaches its highest in individuals aged 75–84 [8]. However, due to the rarity of primary malignant brain tumors and other CNS tumors, they are not included in large-scale mortality trend analysis despite causing significant morbidity and mortality [10].

Although a lot of studies have been conducted on the overall disease burden caused by brain tumors and have described the association of mortality with brain and CNS tumors, very few studies have specifically explained the long-term prevalence and mortality trends among the age group of 65 years and older. There is a lack of comprehensive analysis that particularly explains the changes in incidence and death rates over multiple decades, specifically in the older population of the US. To address this gap, this study analyzes the mortality data of five decades from 1968 to 2023 and explains the trends in mortality due to malignant brain tumors among the US adults aged 65 years and above, providing a broad perspective that has not been previously reported in any paper.

2. METHODOLOGY

2.1|Study Setting and Population

This retrospective observational study utilized data from the Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) database publicly available (11). Mortality records were extracted from the mortality data files spanning a 56-year period from 1968 to 2023. The target population included United States adults aged 65 years and older. Deaths

attributable to malignant brain tumors were identified using underlying cause of death classifications across three successive International Classification of Diseases (ICD) systems. Specifically, malignant brain tumor-related deaths were queried using ICD-8 code 191 for data from 1968 to 1978, ICD-9 codes 191 (191.0–191.9) for data from 1979 to 1998, and ICD-10 codes C71 (C71.0–C71.9) for data from 1999 to 2023. Because this study analyzed publicly available, de-identified aggregate government data, institutional review board (IRB) approval and patient consent were not required. The study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (12).

2.2|Data Abstraction

The primary outcomes extracted were the absolute number of malignant brain tumor-related deaths and the corresponding U.S. population sizes. Demographic and geographic variables were abstracted for the entire study period, including age, sex, race/ethnicity, and geographical region. Age was stratified into specific gerontological subgroups to evaluate trends across older populations: 65–74 years, 75–84 years, and 85 years and older. Racial and ethnic categorizations included non-Hispanic White, non-Hispanic Black or African American, and other documented census groups. Geographic variations were analyzed at the state level and across the four standard U.S. Census Bureau regions: Northeast, Midwest, South, and West.

2.3|Statistical Analysis

Crude mortality rates and age-adjusted mortality rates (AAMRs) per 100,000 population were calculated for the overall cohort and stratified by the extracted demographic and geographic variables. AAMRs were standardized to the year 2000 U.S. standard baseline population using population denominators obtained from the National Center for Health Statistics (NCHS) bridged-race population estimates (13,14). To evaluate temporal shifts in mortality, trend analyses were conducted using the Joinpoint Regression Program (Version 5.0.2, National Cancer Institute) (15). Log-linear regression models were employed to determine the annual percent change (APC) and average annual percent change (AAPC) with 95% confidence intervals. The Joinpoint software identifies specific inflection years where significant shifts in mortality trends occur, automatically selecting the simplest trend model that best fits the data. A two-tailed t-test was utilized, with a p -value of < 0.05 considered statistically significant to indicate whether the APC and AAPC slopes diverged meaningfully from the null hypothesis of zero change.

2.4|Forecasting Analysis

To predict future mortality trajectories, an Autoregressive Integrated Moving Average (ARIMA) time-series model was developed to forecast AAMRs up to the year 2035. The forecasting model utilized historical annual mortality rates from 1968 to 2023 to establish its predictive parameters. The adequacy and statistical robustness of the ARIMA model were verified using the Augmented Dickey-Fuller (ADF) test to evaluate data stationarity, alongside the Box-Ljung test to confirm the absence of significant autocorrelation in the model's residuals.

2.5|ICD coding transitions and data harmonization

Because the study period spanned three successive ICD classification systems, mortality data were extracted from three separate query interfaces on CDC WONDER: ICD-8 (1968–1978), ICD-9 (1979–1998), and ICD-10 (1999–2023), and subsequently merged for analysis. Malignant brain tumor deaths were identified using ICD-8 code 191 (1968–1978), ICD-9 code 191 (1979–1998), and ICD-10 code C71 (1999–2023). The ICD-9 to ICD-10 comparability ratio for malignant neoplasms of the brain and CNS is estimated at 0.9691, indicating minimal disruption to trend data at this transition (16). No formal adjustment using comparability ratios was applied, consistent with prior CDC WONDER-based mortality trend studies. Notably, race reporting in the 1968–1998 Compressed Mortality File is restricted to three categories (White, Black, and Other), lacking detailed ethnicity data such as Hispanic origin. To ensure longitudinal consistency across the entire 56-year study period, racial subgroup analysis was specifically focused on White and Black/African American populations. Additionally, improvements in neuroimaging over the study period, particularly the introduction of CT scanning in the 1970s and MRI in the 1980s, may have improved the accuracy of brain tumor diagnoses on death certificates over time (17).

3. RESULT

A total of 311,680 deaths attributable to malignant brain tumors were identified among United States adults aged 65 years and older during the 56-year study period from 1968 to 2023. Over the entire study period, the overall mean age-adjusted mortality rate (AAMR) was 15.2 per 100,000. It showed a significant upward trajectory, increasing from 6.3 per 100,000 (95% CI, 6.0–6.6) in 1968 to an observed peak of 18.3 per 100,000 (95% CI, 18.0–18.7) in 2021. Overall, the average annual percent change (AAPC) for the 56-year period was 1.91% (95% CI, 1.62–2.20; $P < 0.001$).

3.1|Annual Trends

Joinpoint regression analysis of the overall cohort identified four distinct trend segments: a rapid initial increase from 1968 to 1975 (Annual Percent Change [APC], 4.44%; $P < 0.001$), followed by the steepest acceleration from 1975 to 1980 (APC, 9.47%; $P < 0.001$), and continued slower growth from 1980 to 1991 (APC, 2.33%; $P < 0.001$). This was followed by a slight decline from 1991 to 2006 (APC, -0.32%; $P = 0.005$) before rebounding with a steady increase from 2006 to 2023 (APC, 0.46%; $P < 0.001$) [Supplementary table 2, Supplementary Fig. 1].

3.2|ARIMA Trends

To project the future trajectories of malignant brain tumor mortality in the older adult population, an Autoregressive Integrated Moving Average (ARIMA) model was applied to historical AAMR data (1968–2023). Model adequacy was statistically confirmed by the Augmented Dickey-Fuller (ADF) test ($P = 0.63$, confirming appropriate differencing for stationarity) and the Box-Ljung test ($P = 0.30$, indicating a lack of significant autocorrelation in the residuals). The forecasting model predicts a continuous, stable plateauing trend in mortality rates over the next decade. The projected AAMR is expected to slightly rise

from the 2023 baseline, reaching 17.91 per 100,000 (95% CI, 17.02–18.81) in 2024 and increasing to 18.07 per 100,000 (95% CI, 12.06–24.08) by the year 2035 [Supplementary Fig. 5].

3.3|Trends Stratified by Ethnicity/Race

Racial disparities were evident in the longitudinal trends. The White population accounted for the vast majority of deaths and exhibited a steady increase over the full period (AAPC, 1.96%; 95% CI, 1.67–2.26; $P < .001$), reaching an AAMR [Supplementary table 4, Supplementary Fig. 3] of 19.7 per 100,000 in 2023. However, mortality trends were most pronounced among the Black or African American population, which demonstrated a steeper average annual increase over the study period (AAPC, 2.70%; 95% CI, 2.10–3.31; $P < .001$). The AAMR for Black individuals rose from 2.4 per 100,000 in 1968 to 10.0 per 100,000 in 2023. Joinpoint models revealed that the Black population experienced an extreme early spike from 1968 to 1979 (APC, 9.42%; $P < 0.001$), remaining on a gradual upward trajectory through 2023 (APC, 0.28%; $P = 0.01$) [Supplementary table 2].

3.4|Trends Stratified by State

At the state level, the highest observed overall AAMR was noted in Vermont (23.5 per 100,000), followed closely by Oklahoma (21.9 per 100,000), South Dakota (21.9 per 100,000), Mississippi (21.8 per 100,000), and Idaho (21.7 per 100,000). On the other hand, the lowest AAMRs were recorded in the District of Columbia (12.1 per 100,000) and Hawaii (9.2 per 100,000) [Supplementary table 6].

3.5|Trends Stratified by Age

The mortality burden varied substantially across gerontological age groups. The 65–74 years age group had the highest absolute mortality burden, accounting for 167,418 deaths. The crude rate for this age group rose from 8.4 per 100,000 in 1968 to 15.0 per 100,000 in 2023. However, older subgroups showed the most dramatic rate increases. The crude rate for adults aged 75–84 years increased more than fourfold, from 5.0 per 100,000 in 1968 to 21.2 per 100,000 in 2023 (104,785 total deaths). The 85 years and older cohort demonstrated the highest relative increase, with rates climbing from 1.1 per 100,000 in 1968 to 21.1 per 100,000 in 2023 (39,477 total deaths).

3.6|Trends Stratified by Gender

Both male and female populations showed significant increases in mortality [Supplementary table 3, Supplementary Fig. 2], though the trajectory and absolute rates differed. Males had higher overall mortality rates compared to females (AAMR of 21.6 per 100,000 for males vs. 15.1 per 100,000 for females in 2023). However, females had a slightly higher annual increase in mortality over the entire study period compared to males (AAPC: 1.95% vs. 1.82%; both $P < .001$). Joinpoint analysis for males showed the sharpest increase between 1975 and 1979 (APC, 10.89%; $P < .001$), whereas females saw their steepest rise slightly later, between 1974 and 1981 (APC, 8.37%; $P < .001$) [Supplementary table 2].

3.7|Trends Stratified by Census Region

Significant regional and state-level variations in malignant brain tumor mortality [Supplementary table 5, Supplementary Fig. 4] were observed. Geographically, mortality trends were steepest in the South census region, which demonstrated the highest average annual increase (AAPC, 2.19%; 95% CI, 1.94–2.44; $P < .001$). This was followed by the Northeast (AAPC, 1.81%), West (AAPC, 1.79%), and Midwest (AAPC, 1.78%) [Supplementary table 2].

4. DISCUSSION

The present study represents one of the most comprehensive studies in terms of mortality rates due to brain tumors in the elderly population in the United States over a period of more than five decades, from 1968 to 2023. Age-adjusted mortality rates due to brain tumors have steadily increased from 6.3 per 100,000 in 1968 to a peak of 18.3 per 100,000 in 2021, and are expected to further increase up to 2035. Despite advances in neuro-oncology, brain tumors remain a significant cause of mortality in the elderly population in the United States.

A possible cause for the increasing mortality rate in the earlier decades is the improvement in diagnostic capabilities. Advances in computed tomography and magnetic resonance imaging have improved the ability to classify intracranial tumors, leading to better classification in mortality records. Despite these advances, the prognosis for brain tumor patients remains poor. Malignant primary brain tumors result in over 15,000 deaths annually in the U.S. (18). Despite advances in surgery, radiation, and chemotherapy, no significant improvement in prognosis has been observed. Glioblastomas, which account for almost half of all malignant brain tumors, have a mean survival of 12 to 15 months (20).

Significant age-related differences were observed. The highest number of mortalities occurred in the 65 to 74 years age group, while the highest percentage increase was seen in individuals aged 75 to 84 years and ≥ 85 years. This may be attributed to the accumulation of genetic mutations and weakening of the immune system in older individuals (21).

Significant sex-based differences were observed. Although mortality rates were higher in men, the increase over time was slightly greater in women. These findings align with existing literature showing a higher prevalence of gliomas in men, likely due to hormonal and genetic predispositions (22). Racial differences were also observed, with the highest increase in mortality in the Black population. Similar findings have been reported in previous studies showing poorer cancer outcomes among minority populations, which may be related to inequities in healthcare access (23).

Geographical variation was another important factor. States in the Southern region experienced a greater increase in death rates, consistent with studies highlighting regional disparities in cancer outcomes related to economic factors, healthcare access, and health-seeking behaviour (24). Higher age-adjusted mortality rates were also observed in certain states, which may reflect population characteristics and limited access to specialized neuro-oncologic care, particularly in rural areas (25).

Forecasting based on ARIMA models indicates that mortality rates will continue to rise through 2035. This trend is consistent with global patterns showing an increasing cancer burden with aging populations (26).

Advances in molecular biology offer potential for improving future outcomes. Molecular classification, targeted therapy, and immunotherapy show promise in the management of malignant brain tumors (19). Additionally, artificial intelligence-based imaging techniques may improve diagnostic accuracy and treatment planning, potentially helping to control mortality rates (27).

The strengths of this study include the use of a representative dataset spanning more than five decades and robust statistical methods such as Joinpoint regression and ARIMA forecasting. Limitations include potential inaccuracies in mortality data based on death certificates and the lack of detailed clinical information regarding tumor type, stage, and treatment modalities.

5. FUTURE IMPLICATIONS

The persistence of this increase in brain tumor-related mortality has prompted calls to increase focus on neuro-oncology research, treatment, and health care planning. Given that this population will continue to age, it is likely that the incidence of malignant brain tumors will persistently increase. Therefore, early detection and treatment of brain tumors will continue to be of importance. With advances in molecular medicine, targeted therapy, and immunotherapy, patients may have improved outcomes with the development of individualized medicine. Additionally early detection may be increased with advances in emerging technology to aid in diagnostics such as artificial intelligence (AI) assisted imaging. The differences between racial groups as well as geographic locations noted in this study may further drive importance to develop health policies that can address the ability for patients to receive care from neuro oncology subspecialists. Future studies should consider including epidemiology to understand what factors may play a role in these differences to inform targeted health interventions to improve health outcomes and reduce mortality rates among vulnerable populations.

6. CONCLUSION

In conclusion, our national-population based study shows that mortality rates associated with brain tumors in adults aged ≥ 65 years have been rising in the United States during the past five decades. Increases have varied by sex, race, and geographic region suggesting that females, blacks, and those in the South have experienced a more rapid rise in brain tumor-related mortality. Forecasting models project that these increases will continue through 2035. These results highlight the burden that malignant brain tumors continue to have as a long-term public health problem among older adults. Additionally, our study highlights the importance of monitoring long-term trends in brain tumor-related mortality and the development of improved methods of early detection, treatment, and healthcare delivery. Furthermore, characteristics identified in this study and future advancements in neuro-oncology

will be vital to decreasing brain tumor-associated mortality and improving survival among elderly populations.

7. Declarations and Acknowledgements

Disclosure: The author(s) declare no conflict of interest.

Funding: No funds, grants, or other support were received for this study.

Conflict of Interest: The Authors declare that they have no conflicts of interest. We acknowledge and adhere to Conflict of Interest Policy.

Ethical Approval: This study used publicly available, de-identified data from CDC WONDER database. AS no human subjects were involved, formal ethical approval was not required.

Consent to participate: Not applicable, as the study used publicly available, de-identified data.

Consent to publication: All authors have reviewed the manuscript and provide consent for its publication.

Availability of data and material: All data used in this study are publicly available on CDC WONDER database.

Code availability:

. Joinpoint Regression software (version 5.4.0) was used for analysis.

. Grammarly software was used to check Grammar.

. R Studio for ARIMA Forecasting.

Clinical Trial Number: Not Applicable

Author's Contribution: **Ali Zubair:** conceptualization, data extraction, data curation, project administration, supervision, writing – original draft, writing – reviewing & editing **Anchit Chauhan:** conceptualization, supervision, results, methodology, writing – review & editing, project administration; **Amatul Hadi Hamdana:** discussion, reference management, writing – review & editing; **Falak Naz:** Data analysis, Table handling, writing original draft, writing – review & editing; **Minal Sajjad :** Introduction, data curation, writing – review & editing; **Kanchan Chaudhary:** writing – original draft, project administration, writing – review & editing; **Muhammad sohaib anwer:** senior reviewer, writing – review & editing; **Maaz Ahmed:** resources, writing – review & editing; ; **Wishad waris:** writing – original draft, writing – review & editing; **Rida Shakeel:** writing review and editing, **Hakim Ullah Wazir:** Correspondence, writing – original draft, writing – review & editing

References

1. Ostrom QT, Price M, Neff C, Cioffi G, Waite KA, Kruchko C, Barnholtz-Sloan JS. CBTRUS Statistical Report: Primary Brain and Other Central Nervous System Tumors Diagnosed in the United States in 2016-2020. *Neuro Oncol*. 2023 Oct 4;25(12 Suppl 2):iv1-iv99. doi: 10.1093/neuonc/noad149. PMID: 37793125; PMCID: PMC10550277.
2. Salari N, Ghasemi H, Fatahian R, Mansouri K, Dokaneheifard S, Shiri MH, Hemmati M, Mohammadi M. The global prevalence of primary central nervous system tumors: a systematic review and meta-analysis. *Eur J Med Res*. 2023 Jan 20;28(1):39. doi: 10.1186/s40001-023-01011-y. PMID: 36670466; PMCID: PMC9854075.
3. Dantio CD, Fasoranti DO, Teng C, Li X. Seizures in brain tumors: pathogenesis, risk factors and management (Review). *Int J Mol Med*. 2025 May;55(5):82. doi: 10.3892/ijmm.2025.5523. Epub 2025 Mar 21. PMID: 40116082; PMCID: PMC11964414.
4. Fan Y, Zhang X, Gao C, Jiang S, Wu H, Liu Z, Dou T. Burden and trends of brain and central nervous system cancer from 1990 to 2019 at the global, regional, and country levels. *Arch Public Health*. 2022 Sep 17;80(1):209. doi: 10.1186/s13690-022-00965-5. PMID: 36115969; PMCID: PMC9482735.
5. Nayak L, Iwamoto FM. Primary brain tumors in the elderly. *Curr Neurol Neurosci Rep*. 2010 Jul;10(4):252-8. doi: 10.1007/s11910-010-0110-x. PMID: 20461477; PMCID: PMC7398448.
6. Ilic I, Ilic M. International patterns and trends in the brain cancer incidence and mortality: An observational study based on the global burden of disease. *Heliyon*. 2023 Jul 13;9(7):e18222. doi: 10.1016/j.heliyon.2023.e18222. PMID: 37519769; PMCID: PMC10372320.
7. GBD 2021 US CNS Cancer Collaborators. Burden of Central Nervous System Cancer in the United States, 1990-2021. *JAMA Neurol*. 2026;83(1):35–48. doi:10.1001/jamaneurol.2025.4286
8. Schaff LR, Mellinghoff IK. Glioblastoma and Other Primary Brain Malignancies in Adults: A Review. *JAMA*. 2023 Feb 21;329(7):574-587. doi: 10.1001/jama.2023.0023. PMID: 36809318; PMCID: PMC11445779.
9. Tan JY, Thong JY, Yeo YH, Mbenga K, Saleh S. Gender, Racial, and Geographical Disparities in Malignant Brain Tumor Mortality in the USA. *Oncology*. 2024;102(8):703-709. doi: 10.1159/000536486. Epub 2024 Jan 27. PMID: 38281482.
10. Thierheimer M, Cioffi G, Waite KA, Kruchko C, Ostrom QT, Barnholtz-Sloan JS. Mortality trends in primary malignant brain and central nervous system tumors vary by histopathology, age, race, and sex. *J Neurooncol*. 2023 Mar;162(1):167-177. doi: 10.1007/s11060-023-04279-6. Epub 2023 Mar 16. PMID: 36928698; PMCID: PMC10050015.
11. <https://wonder.cdc.gov/>
12. <https://pubmed.ncbi.nlm.nih.gov/18064739/> von Elm, Erik et al. "The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies." *Lancet* (London, England) vol. 370,9596 (2007): 1453-7. doi:10.1016/S0140-6736(07)61602-X

13. <https://pubmed.ncbi.nlm.nih.gov/9796247/> Anderson, R N, and H M Rosenberg. "Age standardization of death rates: implementation of the year 2000 standard." National vital statistics reports : from the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System vol. 47,3 (1998): 1-16, 20.
14. <https://pubmed.ncbi.nlm.nih.gov/14556588/> Ingram, Deborah D et al. "United States Census 2000 population with bridged race categories." Vital and health statistics. Series 2, Data evaluation and methods research ,135 (2003): 1-55.
15. <https://surveillance.cancer.gov/joinpoint/>
16. <https://pubmed.ncbi.nlm.nih.gov/11381674/> Anderson, R N et al. "Comparability of cause of death between ICD-9 and ICD-10: preliminary estimates." National vital statistics reports : from the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System vol. 49,2 (2001): 1-32.
17. <https://pmc.ncbi.nlm.nih.gov/articles/PMC8523063/> Dillon WP. 50th anniversary of computed tomography: past and future applications in clinical neuroscience. J Med Imaging (Bellingham). 2021 Sep;8(5):052112. doi: 10.1117/1.JMI.8.5.052112. Epub 2021 Oct 18. PMID: 34676278; PMCID: PMC8523063.
18. Ostrom QT, Patil N, Cioffi G, et al. CBTRUS statistical report: Primary brain and other central nervous system tumors diagnosed in the United States in 2016–2020. Neuro Oncol. 2023;25(Suppl 4):iv1-iv99.
19. Schaff LR, Mellinghoff IK. Glioblastoma and other primary brain malignancies in adults. JAMA. 2023;329(7):574-587.
20. Fekete B, Werlenius K, Tisell M, et al. What predicts survival in glioblastoma? A population-based study of changes in clinical management and outcome. Front Surg. 2023;10:1249366.
21. Ostrom QT, Gittleman H, Truitt G, et al. CBTRUS statistical report: Primary brain and other CNS tumors diagnosed in the United States. Neuro Oncol. 2018;20(Suppl 4):iv1-iv86.
22. Sun T, Warrington NM, Luo J, et al. Sex differences in glioblastoma biology and response to therapy. Cancer Res. 2014;74(24):7097-7107.
23. Zavala VA, Bracci PM, Carethers JM, et al. Cancer health disparities in racial/ethnic minorities in the United States. Br J Cancer. 2021;124(2):315-332.
24. Singh GK, Jemal A. Socioeconomic and racial disparities in cancer mortality in the United States. J Environ Public Health. 2017;2017:2819372.
25. Henley SJ, Anderson RN, Thomas CC, et al. Invasive cancer incidence, 2004–2013, and deaths, 2006–2015, in nonmetropolitan and metropolitan counties. MMWR Surveill Summ. 2017;66(14):1-13.
26. Bray F, Laversanne M, Weiderpass E, et al. The ever-increasing importance of cancer as a leading cause of premature death worldwide. Cancer. 2021;127(16):3029-3030.
27. Kickingeder P, Isensee F, Tursunova I, et al. Automated quantitative tumour response assessment of MRI in neuro-oncology using artificial intelligence. Nat Med. 2019;25(3):437-444.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Supplementaryfiles.docx](#)